AD NUMBER

AD914557

NEW LIMITATION CHANGE

TO

Approved for public release, distribution unlimited

FROM

Distribution authorized to U.S. Gov't. agencies only; Test and Evaluation; OCT 1973. Other requests shall be referred to Ballistic Research Lab., Aberdeen Proving Ground, MD.

AUTHORITY

USAARDC ltr 8 Mar 1978

THIS REPORT HAS BEEN DELIMITED
AND CLEARED FOR PUBLIC RELEASE
UNDER DOD DIRECTIVE 5200.20 AND
NO RESTRICTIONS ARE IMPOSED UPON
ITS USE AND DISCLOSURE.

DISTRIBUTION STATEMENT A

APPROVED FOR PUBLIC RELEASE;
DISTRIBUTION UNLIMITED.

BRL MR 2338

BRL

AD

MEMORANDUM REPORT NO. 2338

AD 914557

AN INVESTIGATION INTO THE FLIGHT CHARACTERISTICS OF ROTATING DISCS

by

F. J. Brandon

October 1973

Distribution limited to US Government agencies only; TE 21 NOV 1973
Other requests for this document must be referred to Director, USA Ballistic Research Laboratories, ATTN: AMXBR-SS, Aberdeen Proving Ground, Maryland 21005.

USA BALLISTIC RESEARCH LABORATORIES
ABERDEEN PROVING GROUND, MARYLAND

BALLISTIC RESEARCH LABORATORIES

MEMORANDUM REPORT NO. 2338

OCTOBER 1973

AN INVESTIGATION INTO THE FLIGHT CHARACTERISTICS OF ROTATING DISCS

F. J. Brandon

Exterior Ballistics Laboratory

RDT&E Project No. 1T362301A201

ABERDEEN PROVING GROUND, MARYLAND

BALLISTIC RESEARCH LABORATORIES

MEMORANDUM REPORT NO. 2338

FJBrandon/ds
Aberdeen Proving Ground, Md.
October 1973

AN INVESTIGATION INTO THE FLIGHT CHARACTERISTICS OF ROTATING DISCS

ABSTRACT

Disc shaped parts that are ejected from Beehive and cannister rounds have been found in areas well outside of the expected safety zone. These discs represent a potential danger to friendly troops. The flight characteristics that may have caused the disc to fly errant paths are not known; therefore, a simple test program was undertaken by the Ballistic Research Laboratories to investigate the flight characteristics of a rotating disc. This report discusses these tests and that data obtained.

TABLE OF CONTENTS

PRECEDING PAGE BLANK-NOT FILMED

LIST OF ILLUSTRATIONS

I. INTRODUCTION

Several shell presently in the Army inventory, particularly those with a large parasitic weight, such as Beehive and canister rounds, contain disc shaped components that are ejected in flight. The apparent flight paths of these discs occasionally have ended in areas well outside of that area normally considered the safety zone. During tests fired at the Aberdeen Proving Ground (APG) and other firing ranges, these discs have been found even behind the firing point, and in at least one well documented case, far behind the firing point. As a result of these findings, the safety zone for training and range testing was increased in all directions, which included an unusual rearward requirement, 750 meters deep by 1500 meters wide. This latter requirement was not reasonable for combat training nor for the Test and Evaluation Command (TECOM) testing. A subsequent study indicated that the probability of hitting personnel was so low that a recommendation was made and accepted to rescind the extreme rearward safety zone. Unfortunately, this does not put to rest the question as to just how the discs happened to end up where they did. Nor does it give the users any confidence that it will not happen again. Because of these unanswered questions, the Ballistic Research Laboratories were asked by the Army Materiel Systems Analysis Agency (AMSAA) to look into the flight characteristics of rotating discs.

An incident that occurred a few years ago had required the BRL to make a literature search for data on shapes similar to rotating discs. The results of this search turned up very little information. The available data are mostly for nonspinning disc shaped objects, and the validity of these data* for rapidly rotating discs flying with the rotational axis collinear with the velocity vector is uncertain. Typical data for nonspinning disc shapes are given in Figure 1.

Development of the necessary aerodynamic data to define all possible flight paths for discs would require extensive wind tunnel and free flight range programs. To statistically examine the flight characteristics of rotating discs would require a program equally as extensive, and possibly more expensive, without having any assurance that it would provide any meaningful solutions. The BRL, therefore, decided to undertake a very modest approach in order to develop some testing techniques, and to possibly gain more insight into the problem.

II. TEST PROGRAM AND RESULTS

Three limited test series have been conducted. The aim of the first series was to develop a technique by which a single rotating disc could be launched with the proper attitude, velocity, and rate of

**G. D. Stilley and D. L. Carstens, "Adaptation of the Frisbee Flight Principle to Delivery of Special Ordnance," AIAA Paper No. 72-982, September 1972.*

spin to simulate an ejected disc in flight. At the same time some information mig't be gathered toward understanding the initial flight characteristics of a disc.

A rather large span of velocities and spin rates was desired in order to simulate the spectrum of flight conditions that could exist. The velocity and spin rate ranges desired for the discs were between 300 and 800 m/s and 100 and 500 rps, respectively. The launch vehicle chosen was a 155mm Ballistic Howitzer. It is large enough to hold a reasonable size disc, it could launch the discs at the desired velocities, and it had a variable twist feature, which could impart the desired spin rates. (The variable twist is accomplished by replacing the muzzle extensions which have different twist rates machined in them.) The test was conducted at the BRL Transonic Range Facility with four smear cameras to record sabot separation and the disc's flight attitude and velocity. The cameras were located approximately 3, 5, 8, and 24 meters from the muzzle. A 3 x 3 meter target card was placed 230 meters down range just in front of a large sand pile which could be used to stop the discs.

Table I is a firing log of the seven shots fired through the test arrangement. The first three rounds were proof slug firings which were used to develop a charge/velocity relationship. The other four rounds were used to develop the sabot system. The discs were encased in nylon sabots which had serrated quarters. Three disc cant orientations - 0°, 10°, and 20° - were chosen to simulate some possible conditions other than a nearly perfect component separation. Figure 2 is a composite photograph which shows (upper part) a sabot/disc assembly and a separate disc with the two pins which were added to rotationally lock the sabot and disc together. These pins could be used to measure the spin rate of the disc in flight. The disc is approximately 140mm in diameter, 5mm thick and weighs about 600 grams. The lower part of the figure shows three sabots with the discs canted at the various angles. The results of the firings indicated that the sabots were functioning reasonably, and that the discs flew a normal trajectory for at least the first 25 meters (Figure 3). However, despite the fact that the discs were launched through an open field at a target and sand pile, no discs hit the target and no evidence could be found beyond the last camera as to where the discs may have gone.

The second test series was conducted in cooperation with TECOM's Materiel Test Directorate (MTD). The instrumentation used for this series included smear cameras and a HAWK radar system which had been modified to provide position data as well as velocity (Figure 4). Initial attempts were to fire vertically in order to obtain the longest time of flight. However, there was great difficulty in aligning the radar beam with the disc's trajectory, and after failure to track on the initial attempt, it was decided to reduce the gun elevation to 30°. This angle proved less difficult for radar alignment and four rounds were tracked (Table II). Velocities obtained between cameras indicated that the muzzle velocity was approximately 600 m/s. Figure 5 shows a schematic of the test set-up and Figure 6 is a composite picture of the disc in flight as recorded by the three smear cameras. Figure 7 is an artist's copy of one of the radar records depicting the disc's radial flight velocity as a function of range. The automatic-track-lock-in mode of the radar required about 0.1 seconds to lock on the disc. At that time a velocity of 330 m/s is indicated. The flattened portion of the curve above 0.8 seconds is believed to be the lower threshold velocity, where the radar is designed to stop tracking. Due to some malfunction, no position data were obtained.

The third test series came about on the spur-of-the-moment and was conducted at the National Aeronautics and Space Administration (NASA) Wallops Island facility. The BRL is presently conducting flight characteristic studies of shell at Wallops Island using yawsonde and radar for tracking. The sonde work is being conducted using a 155mm M126 Howitzer which is ballistically similar to the gun used in the previous test series. Because of the similar aspects of the disc and sonde programs, Wallops Island was contacted and it was agreed that the discs could be tested. The only instrumentation used for the series was the FPS-16 tracking radar system (Figure 8). The tracking data obtained were range, azimuth angle, and elevation angle as a function of time. The flight trajectory coordinates and velocity were then reduced from these radar data. Six of the seven rounds fired were tracked, Table III, with tracking data being received for about 5 seconds. The radars do not have automatic acquisition so the operator must manually acquire the target and switch the radar to the automatic track mode. Because of this, the first couple seconds of the flight trajectory were lost. Figure 9 is an artist's copy of one of the radar records. The last 80 meters of the trajectory may be indicative of a disc which has achieved a high lift condition and appears to be sailing.

III. GENERAL COMMENTS ON DISC FLIGHT CHARACTERISTICS

Using the known drag coefficient values for discs, point-mass trajectories have been computed for various launch conditions. Figure 10 shows the rather startling velocity histories of two discs launched at the same gun elevation, but with much different muzzle velocities (800 m/s and 300 m/s). It would appear that it does not matter at what velocity the discs are launched, they will all end up at the same velocity after about a half a second. It must be pointed out that regardless of the fact that the discs have reached the same velocity in the same amount of time, they none-the-less have flown considerably different distances in that time. Figure 11 depicts the velocity history as a function of range. It better illustrates the expected velocity variation for the early flight portion, while showing the trend toward the same velocity at increased ranges.

IV. CONCLUSIONS AND FUTURE PLANS

The results from the program have not yet revealed any answers to the major questions on the flight characteristics of rotating discs. A technique has been developed by which a single disc can be flown, and smear cameras and radar system have been used to record some flight history. Evidence that a disc can obtain a sailing flight condition may have been demonstrated. It appears that unless the disc is flipped by some outside disturbance, it will reach very low subsonic velocities in much less than one second. (No evidence that the disc has flipped in this time span has been found.) Once the disc has reached the low velocities, it does have the potential to fly for several seconds at these speeds. Ranges of nearly 300 meters have been observed for some test flights.

The future plans of the program will remain at modest levels unless greater impetus is imposed by those wanting the answers. There are several possible approaches which could be taken, such as wind tunnel and spark range testing, but these will require a considerably larger funding level. Tests in the subsonic region using a magnetic suspension system to hold and measure the forces acting on the disc are attractive, although conventional tunnel systems can be used to develop most of the necessary data. A continuation of the present testing method will certainly add some limited flight information; however, longer flights are needed. Ejection of a single disc from a projectile flying at a high altitude would give a longer flight time during which the flight history could be observed and recorded. Also, it would be of value to develop a technique by which a rotating disc could be launched in the edge-on condition, in order to gain some information pertinent to the flight characteristics of discs in this mode of flight.

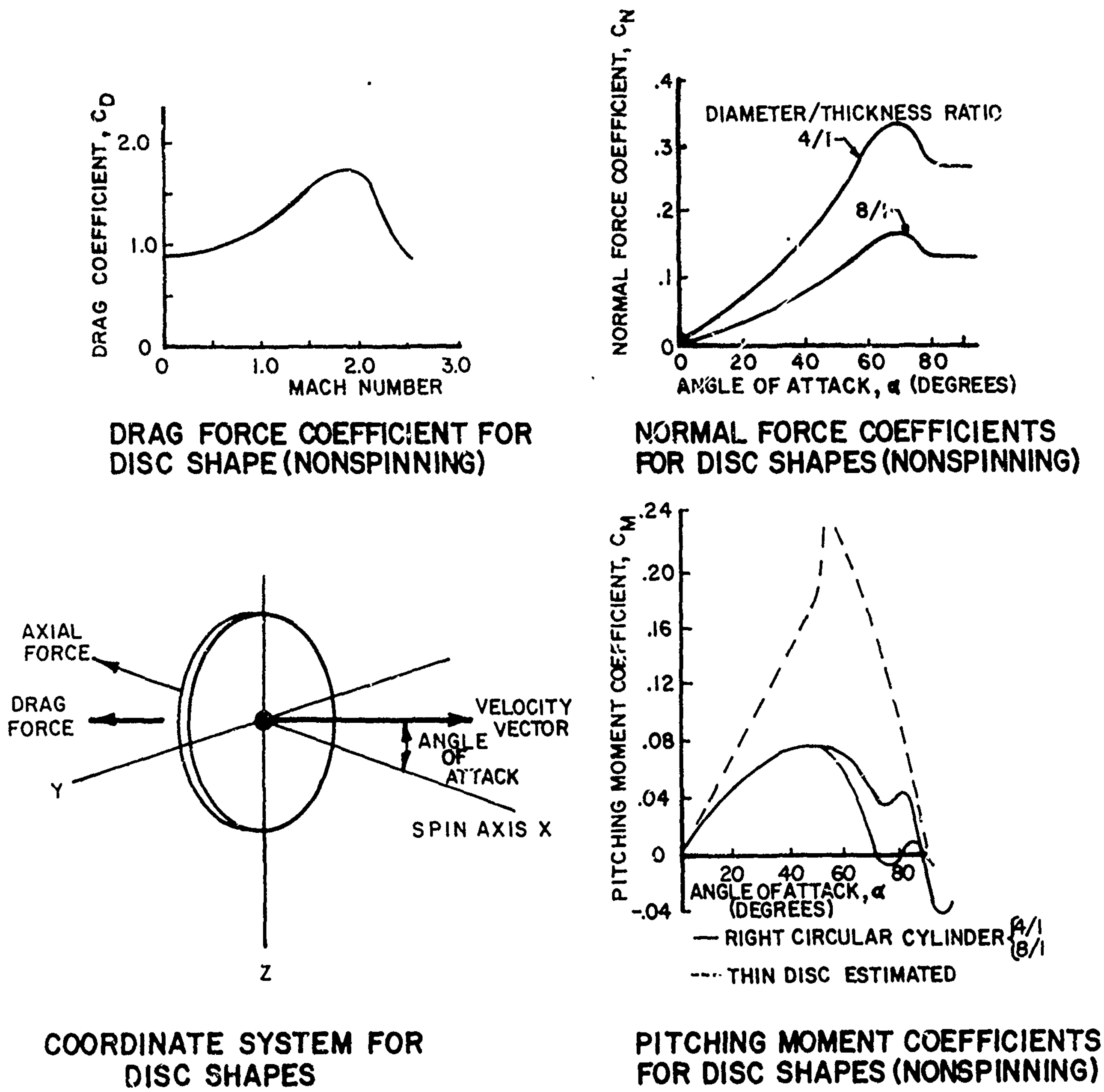


FIGURE I SOME AERODYNAMIC DATA FOR DISC SHAPES (NONSPINNING)

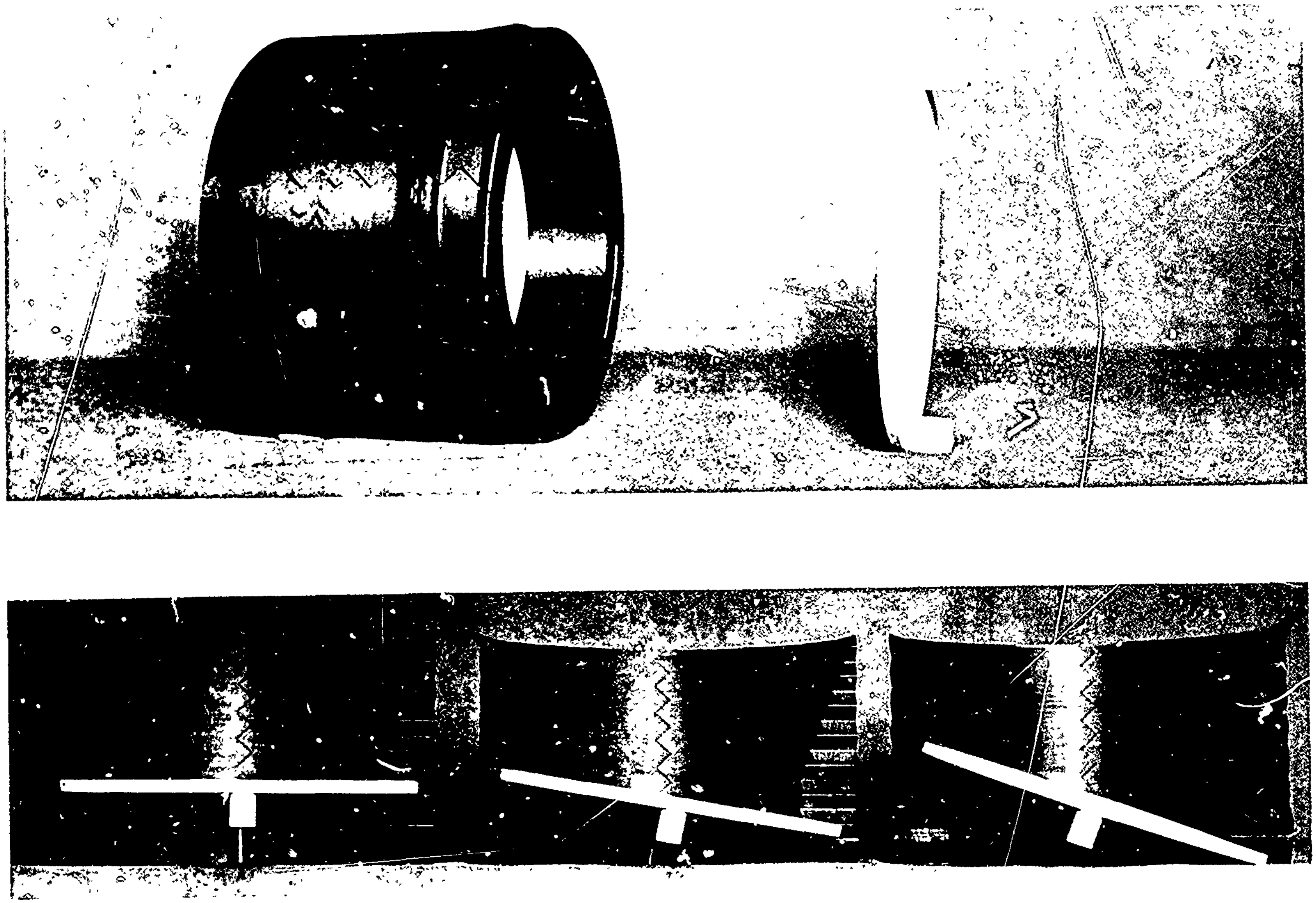
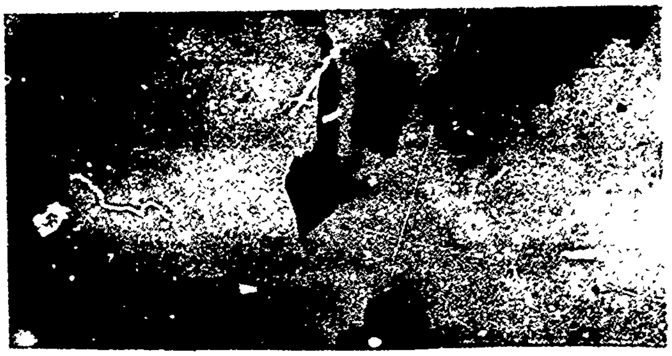
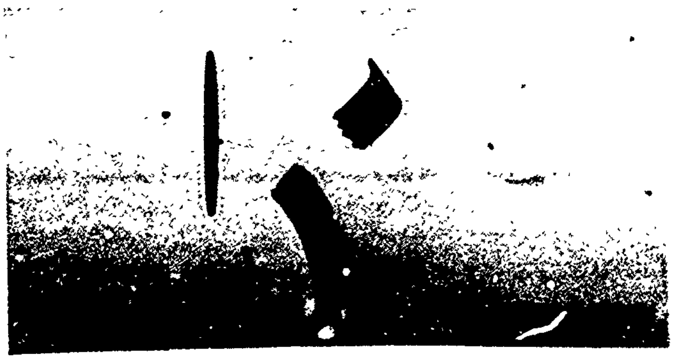


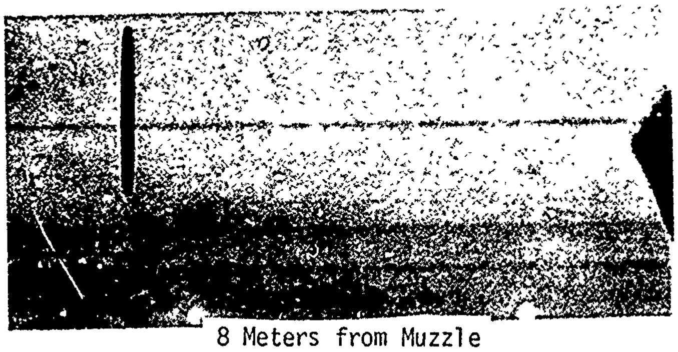
Figure 2. Disc and Sabot Arrangements



3 Meters from Muzzle



5 Meters from Muzzle



8 Meters from Muzzle

24 Meters from Muzzle

Figure 3. Disc and Sabot Separation Sequence

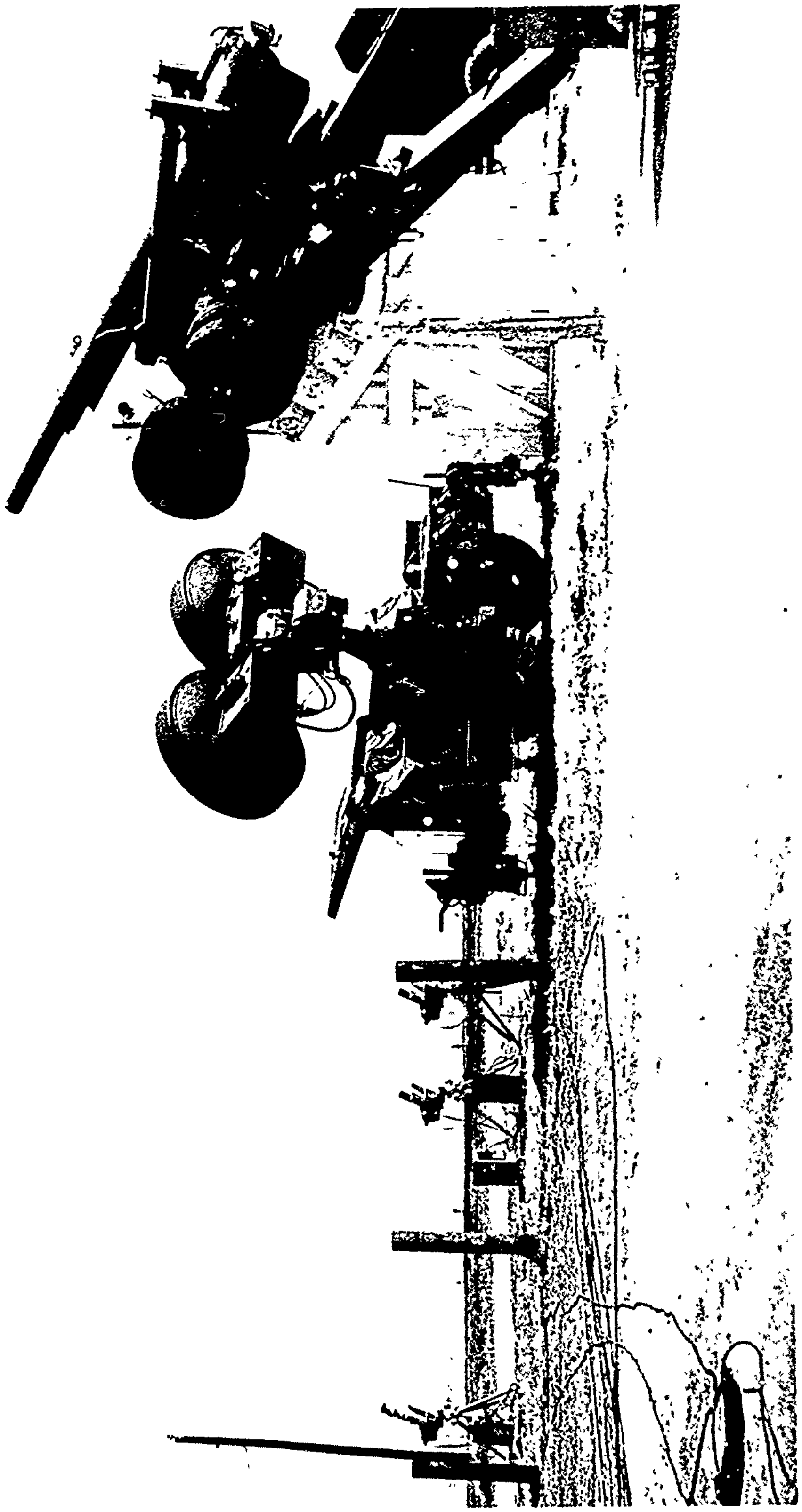


Figure 4. Test Set-Up (MTD "I" Field)

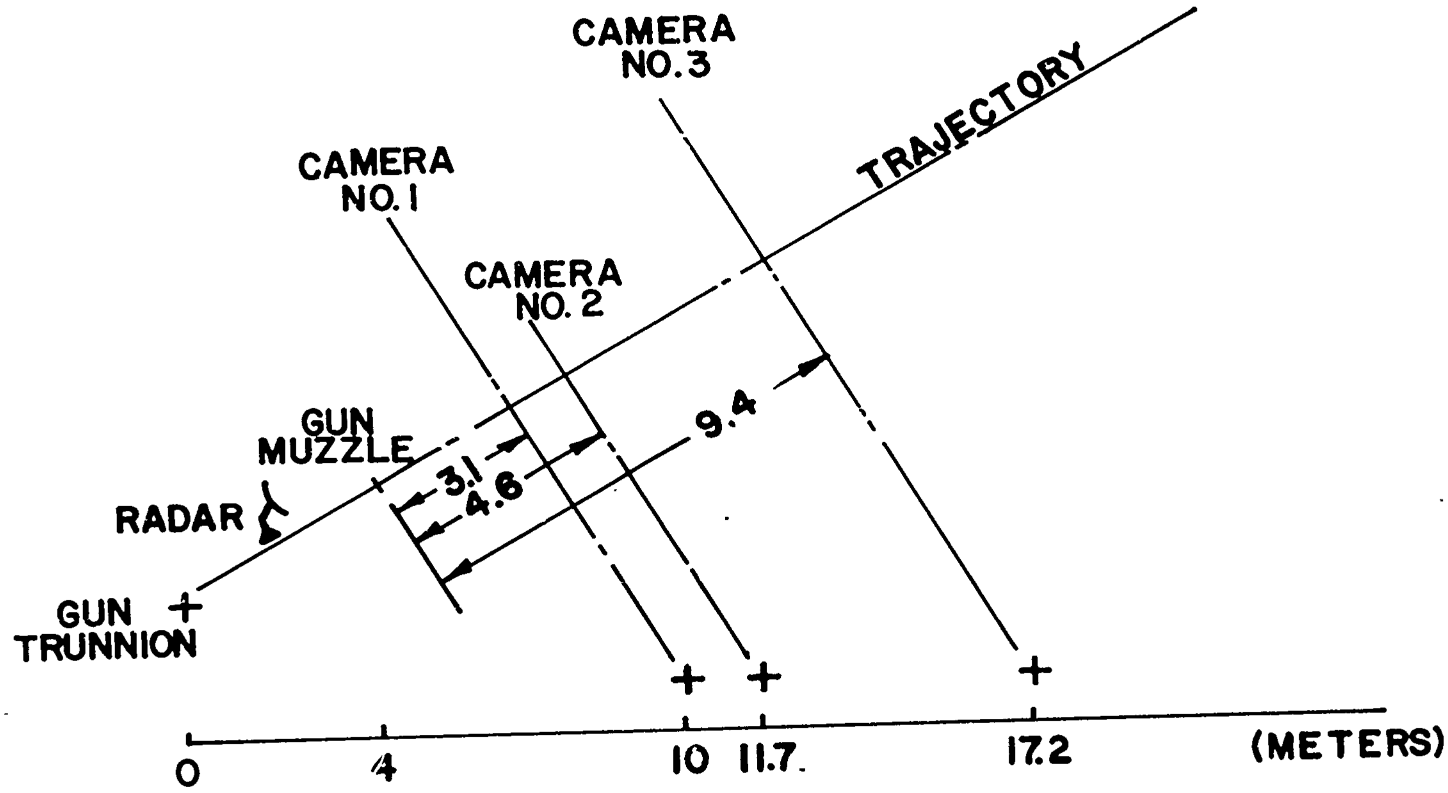


FIGURE 5 SCHEMATIC OF TEST SET-UP FOR DISC PROGRAM
(RANGE I, "I" FIELD, EDGEWOOD)

3.1 Meters from Muzzle

4.6 Meters from Muzzle

9.4 Meters from Muzzle

Figure 6. Disc in Flight (Smear Cameras)

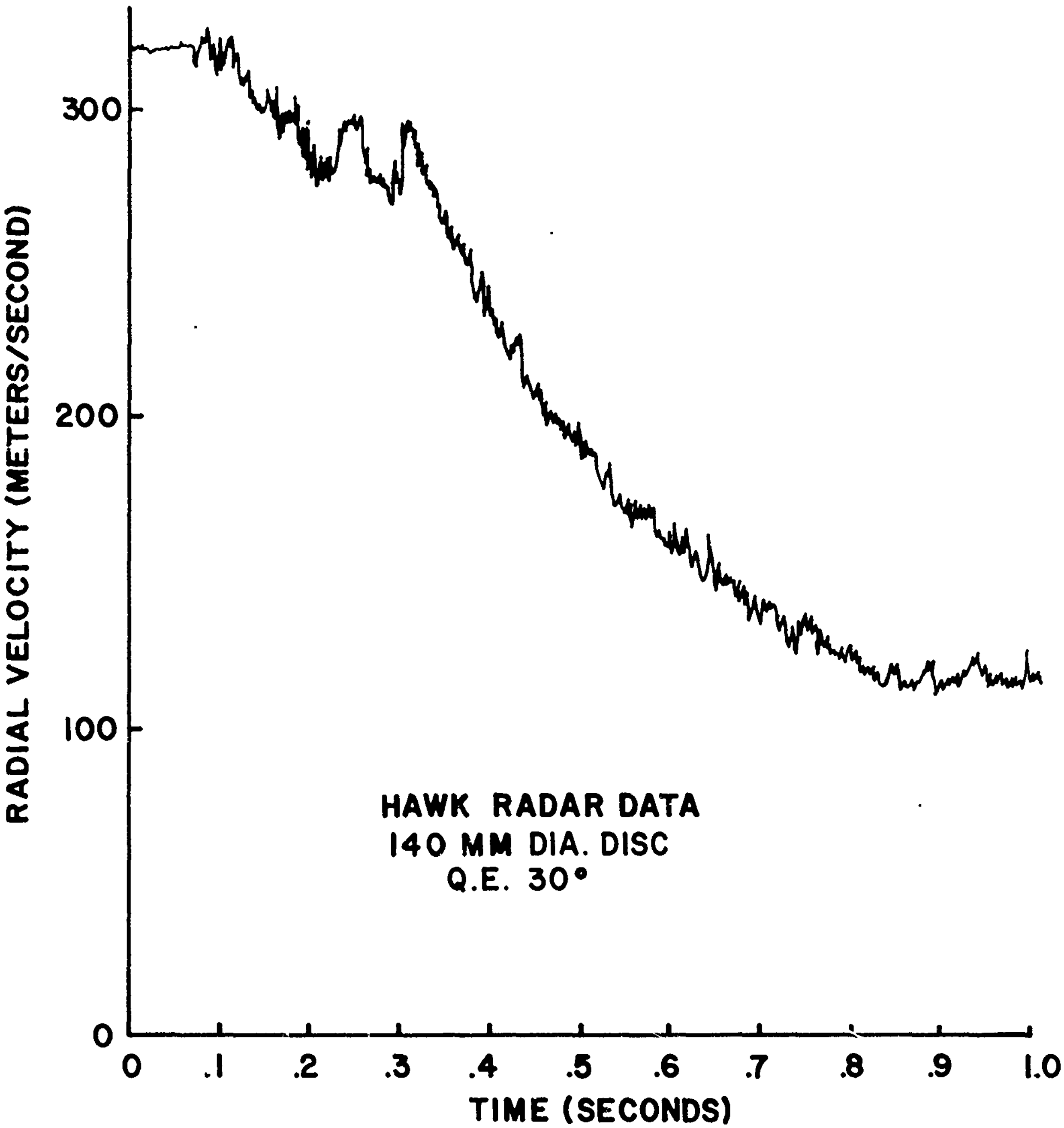


FIGURE 7 RADIAL VELOCITY vs TIME

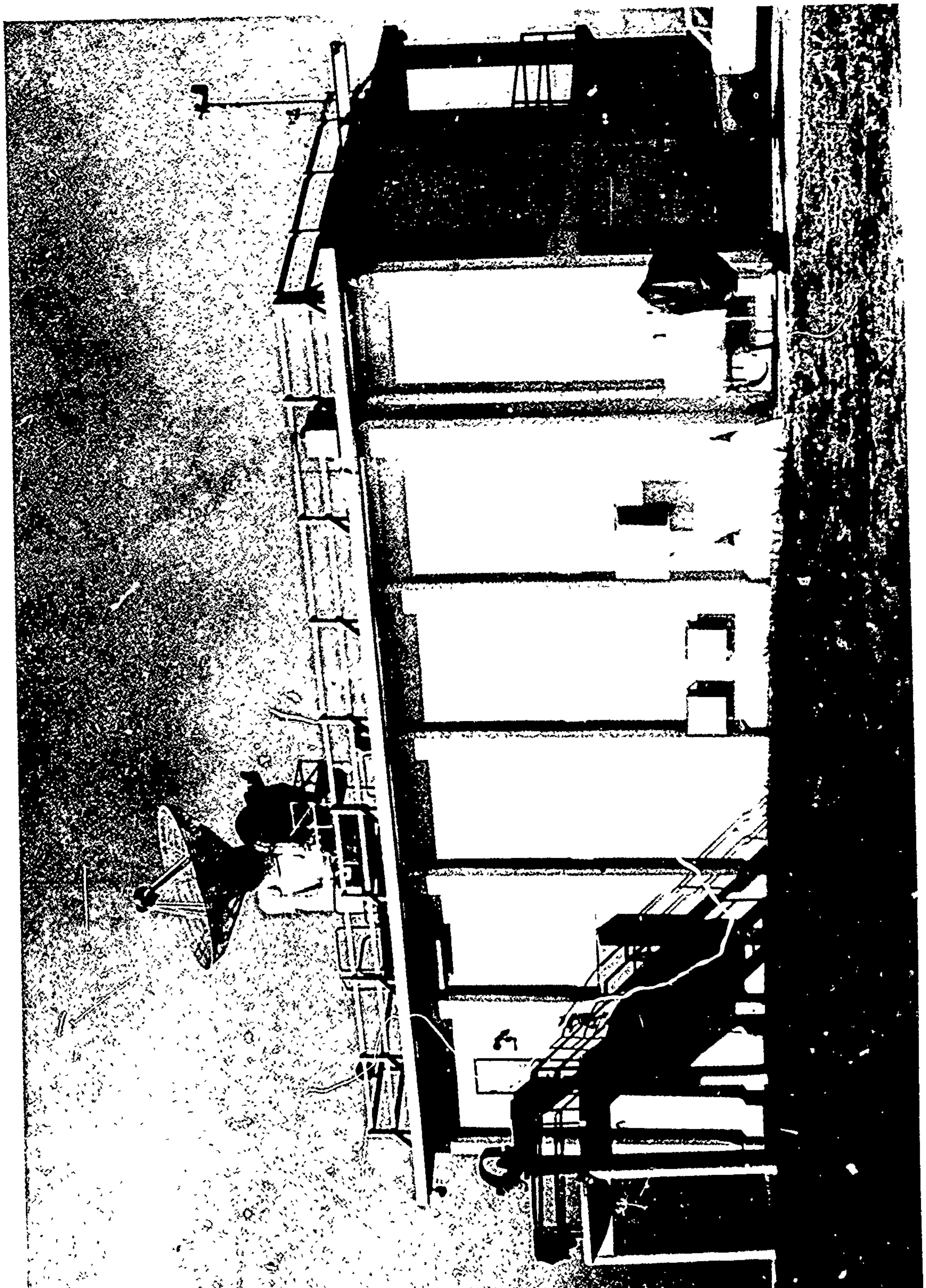


Figure 8. FPS-16 Radar (NASA, Wallops Island, Va.)

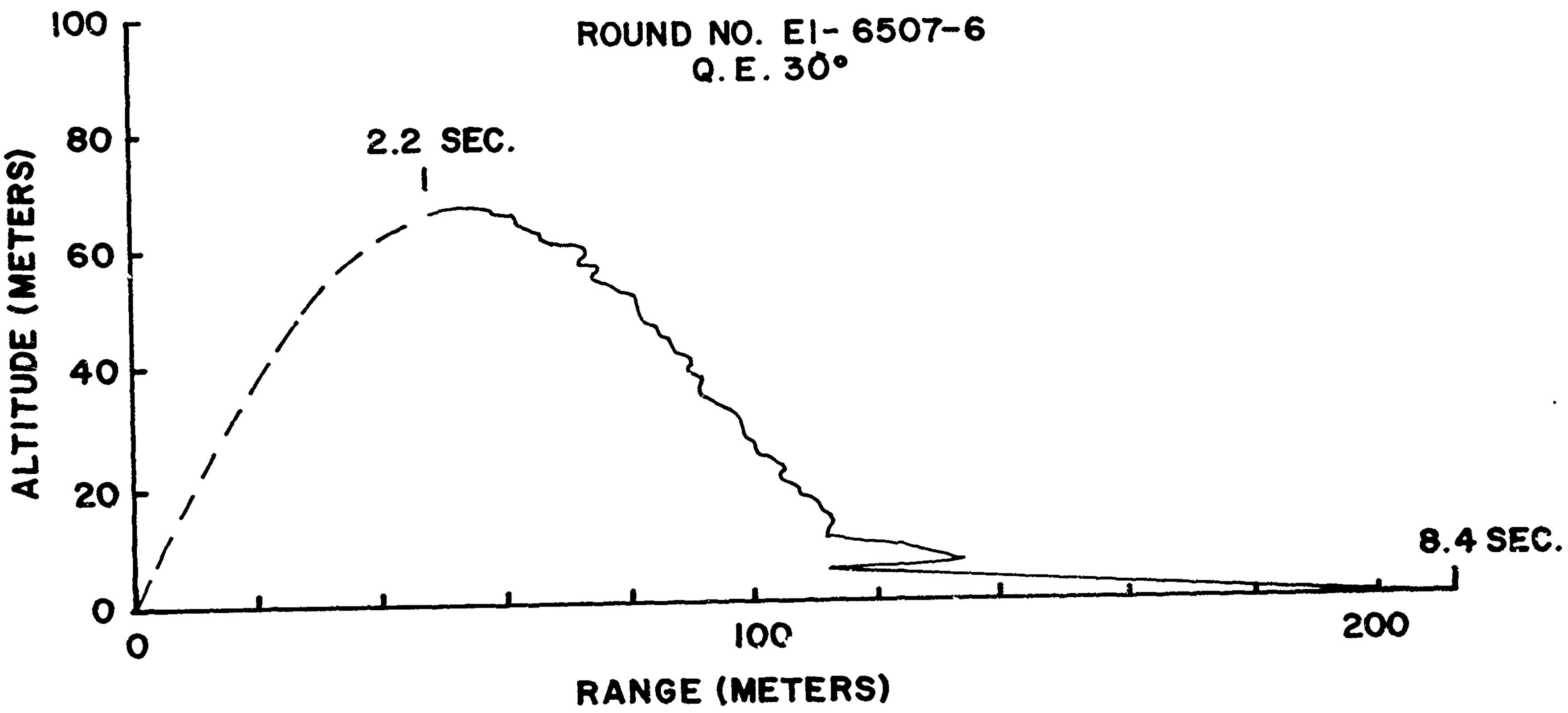


FIGURE 9 FPS 16 RADAR DATA

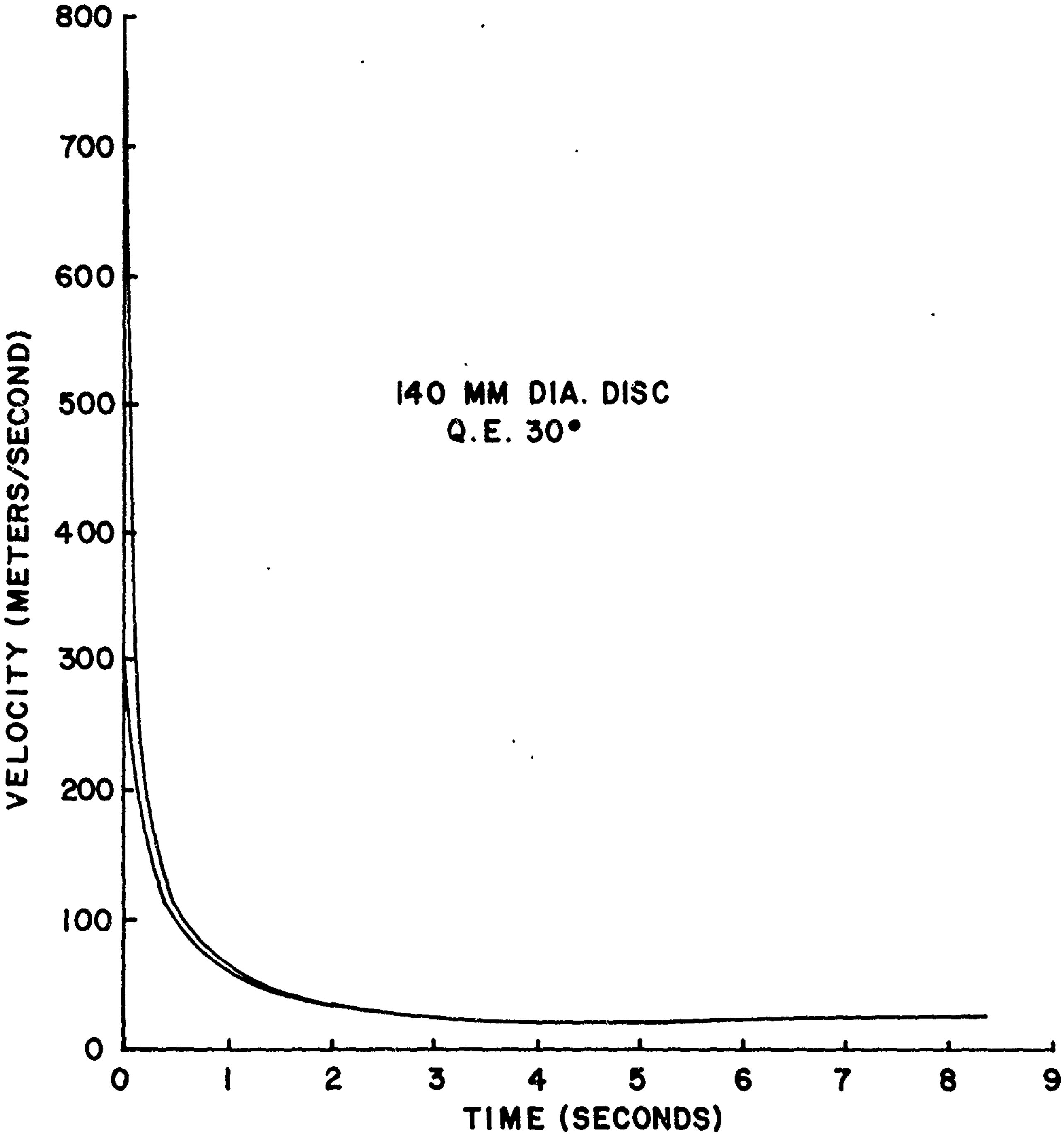


FIGURE 10 VELOCITY vs TIME

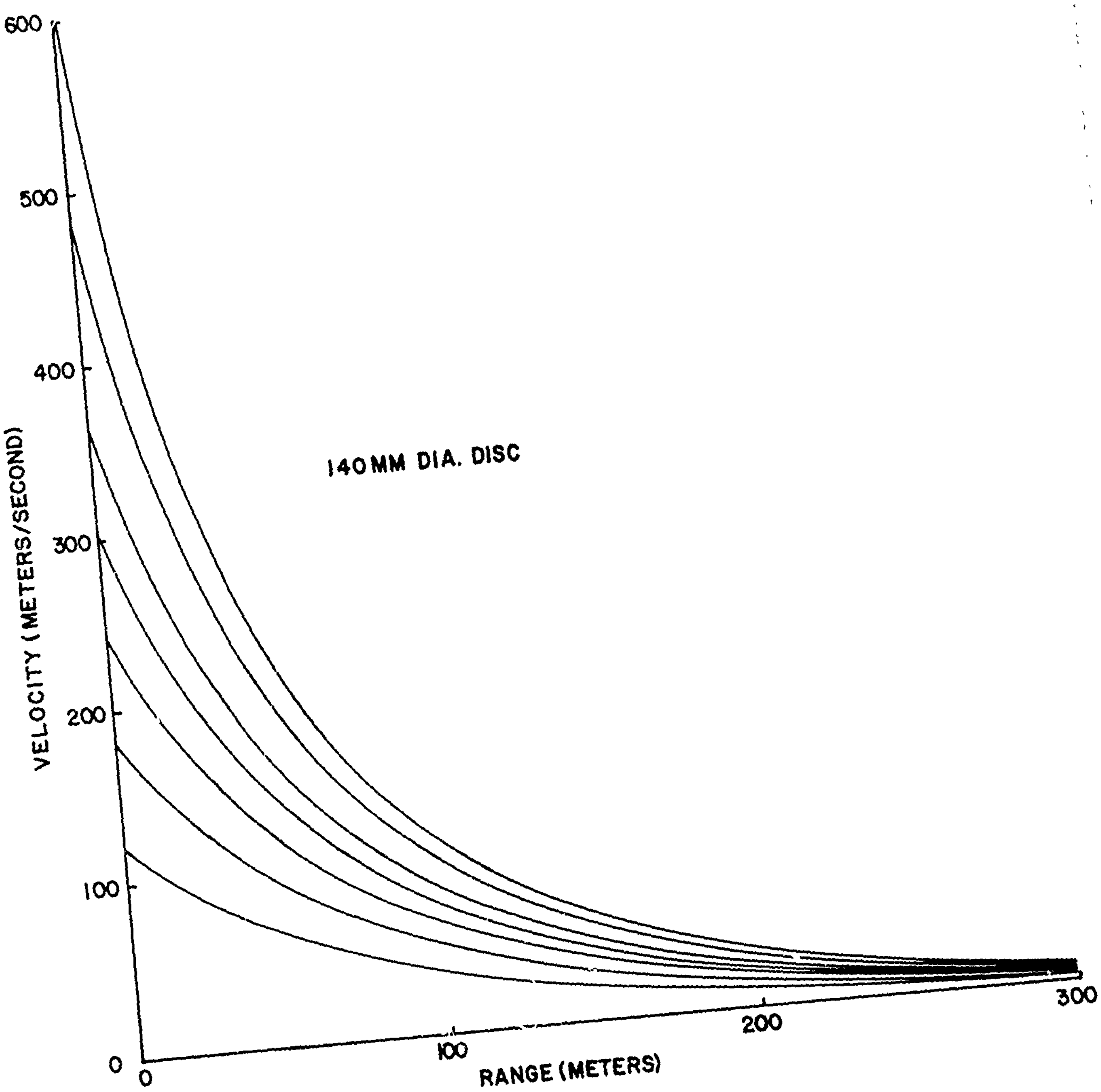


FIGURE II VELOCITY vs RANGE

Table I. Test Series 1 Rotating Disc Program
(BRL Transonic Range)

Test No.	Round No.	Launch Weight (gms)	Charge Weight (gms)	Estimated Muzzle Velocity (m/s)	Remarks
1	10420	1497	198	No Velocity	Proof slug for charge development
2	10421	1497	255	453	Proof slug for charge development
3	10422	1497	142	341	Proof slug for charge development
4	10423	1460	198	345	Disc did not separate from sabot
5	10424	1950	255	No Velocity	Good flight - No roll pins
6	10443	1935	255	379	Good flight - Lost one roll pin
7	10444	1460	213	312	Good flight - One roll pin bent

Table II. Test Series 2 Rotating Disc Program
(MTD I Field Range 1)

Test No.	Round No.	Launch Weight (gms)	Charge Weight (gms)	Estimated Muzzle Velocity (m/s)	Gun Elevation (deg)	Remarks
8	10648	1450	284	None	90	No track
9	10649	1450	284	None	30	Very short tracking time
10	10650	1450	340		30	Very short tracking time
11	10651	1450	340	670	30	No track
12	10652	1450	340	609	30	∿ 0.7 sec. tracking time
13	10653	1450	340	594	30	∿ 0.7 sec. tracking time

Table III. Test Series 3 Rotating Disc Program (NASA, Wallops Island, Va.)

Test No.	Round No.	Launch Weight (gms)	Charge Weight (gms)	Gun Elevation (deg)	Disc Cant Angle (deg)	Remarks
14	EI-6507-1	1352	340	28	0	No track
15	-2	1343	284	28	10	Track from 2.2 to 7.5 sec.
16	-3	1352	284	28	10	Track from 2.4 to 5.7 sec.
17	-4	1352	284	28	0	Track from 2.2 to 5.4 sec.
18	-5	1334	284	28	20	Track from 1.5 to 8.6 sec.
19	-6	1352	284	28	10	Track from 2.2 to 8.4 sec.
20	-7	1365	284	28	20	Track from 2.1 to 7.0 sec.

PRECEDING PAGE BLANK-NOT FILMED

DISTRIBUTION LIST

No. of Copies	Organization
2	Commander Defense Documentation Center ATTN: TIPCR Cameron Station Alexandria, Virginia 22314
1	Commander U. S. Army Materiel Command ATTN: AMCDL 5001 Eisenhower Avenue Alexandria, Virginia 22304
1	Commander U. S. Army Materiel Command ATTN: AMCRD, MG S. C. Meyer 5001 Eisenhower Avenue Alexandria, Virginia 22304
1	Commander U. S. Army Materiel Command ATTN: AMCRD, Dr.J.V.R.Kaufman 5001 Eisenhower Avenue Alexandria, Virginia 22304
1	Commander ATTN: AMCRD-T 5001 Eisenhower Avenue Alexandria, Virginia 22304
1	Commander U. S. Army Materiel Command ATTN: AMCSF-E 5001 Eisenhower Avenue Alexandria, Virginia 22304
1	Commander U. S. Army Aviation Systems Command ATTN: AMSAV-E 12th and Spruce Streets St. Louis, Missouri 63166
1	Director U.S. Army Air Mobility Research and Development Laboratory Ames Research Center Moffett Field, California 94035
1	Commander U.S. Army Electronics Command ATTN: AMSEL-RD Fort Monmouth, New Jersey 07703
1	Commander U.S. Army Missile Command ATTN: AMSMI-R Redstone Arsenal, Alabama 35809
1	Commander U.S. Army Tank Automotive Command ATTN: AMSTA-RHFL Warren, Michigan 48090
2	Commander U.S. Army Mobility Equipment Research & Development Center ATTN: Tech Docu Cen, Bldg. 315 AMSME-RZT Fort Belvoir, Virginia 22060
1	Commander U.S. Army Armament Command Rock Island, Illinois 61202
1	Commander Armor and Engineering Board ATTN: STEBB-ADS Fort Knox, Kentucky 40121
1	Commander Jefferson Proving Ground ATTN: STEJP-SO Madison, Indiana 47250

DISTRIBUTION LIST (Continued)

No. of Copies	Organization
1	Commander Yuma Proving Ground ATTN: STEYP-SAF Yuma, Arizona 85364
1	Commander U.S. Army Arctic Test Center ATTN: STEAC-AD-S Fort Greely, Alaska APO Seattle, Washington 98733
1	Commander U.S. Army Tropic Test Center ATTN: STETC-MO-A Post Office Drawer 942 Fort Clayton, Canal Zone
1	Director U.S. Army Advanced Materiel Concepts Agency 2461 Eisenhower Avenue Alexandria, Virginia 22314
1	Commander U.S. Army Harry Diamond Laboratories ATTN: AMXDO-TI Washington, DC 20438
1	Commander U.S. Army Armor School ATTN: Armor Agency CDCAR-MMBT, Mr.M.Falkouich Fort Knox, Kentucky 40121
1	Commander U.S. Army Field Artillery Center ATTN: ATSFA-CT, Col. Longmore Fort Sill, Oklahoma 73503
1	Commander U.S. Army Infantry School ATTN: ATSH-I-MS-F Mr. A. Brown Fort Benning, Georgia 31905

Aberdeen Proving Ground

Cmdr, APG
ATTN: STEAP-MT-E
Cmdr, USATECOM
ATTN: AMSTE-ST
Dir, USAMSAA
ATTN: AMXSY, Mr. M. Smith
AMXSY-GA, Mr.G.Beichler
AMXSY-DL, Mr.K.Myers
AMXSY-GS, Mr.J.Blomquist
AMXSY-GL, Mr.W.Clifford

Unclassified
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author)
U. S. Army Ballistic Research Laboratories
Aberdeen Proving Ground, Maryland 21005

2a. REPORT SECURITY CLASSIFICATION
Unclassified

2b. GROUP

3. REPORT TITLE
AN INVESTIGATION INTO THE FLIGHT CHARACTERISTICS OF ROTATING DISCS

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

5. AUTHOR(S) (First name, middle initial, last name)
F. J. Brandon

6. REPORT DATE
OCTOBER 1973

7a. TOTAL NO. OF PAGES
28

7b. NO. OF REFS
1

8a. CONTRACT OR GRANT NO.

b. PROJECT NO. 1T362301A201

c.

d.

9a. ORIGINATOR'S REPORT NUMBER(S)
BRL MEMORANDUM REPORT NO. 2338

9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

NOV 1973

10. DISTRIBUTION STATEMENT
Distribution limited to US Government agencies only. Other requests for this document must be referred to Director, USA Ballistic Research Laboratories, ATTN: AMXBR-SS, Aberdeen Proving Ground, Maryland 21005.

11. SUPPLEMENTARY NOTES

12. SPONSORING MILITARY ACTIVITY
U. S. Army Materiel Command
5001 Eisenhower Avenue
Alexandria, Virginia 22304

13. ABSTRACT

Disc shaped parts that are ejected from Beehive and cannister rounds have been found in areas well outside of the expected safety zone. These discs represent a potential danger to friendly troops. The flight characteristics that may have caused the disc to fly errant paths are not known; therefore, a simple test program was undertaken by the Ballistic Research Laboratories to investigate the flight characteristics of a rotating disc. This report discusses these tests and that data obtained.

UNCLASSIFIED
Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Rotating Disc Disc Flight Characteristics Beehive Rounds Cannister Rounds Radar Trajectories						

UNCLASSIFIED
Security Classification